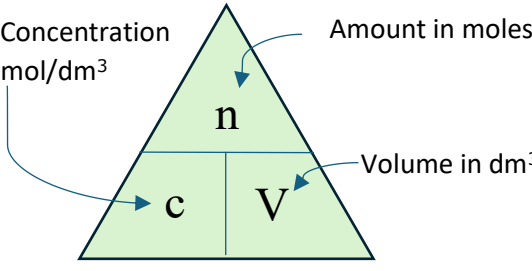# Unit 1: Structure, Bonding and Introduction to Organic Chemistry

Topic 1: Formulae, Equations and Amount of Substance

Application of ideas from this topic will be applied to all other units.

Students will be assessed on their ability to:

1.1	know the terms 'atom', 'element', 'ion', 'molecule', 'compound', 'empirical formula' and 'molecular formula'
	An **atom** is the smallest, electrically neutral particle of an element that can take part in a reaction An **element** is a substance which cannot be broken down into simpler substances by chemical means and it can contain only one type of atom An **ion** is an electrically charged atom or group of atoms that has gained or lost electrons to become a charged species A **molecule** is the smallest electrically neutral particle of an element or compound which can exist on its own and is formed by two or more atoms bonded together A **compound** is a pure substance which can be broken down into simpler substances by chemical means and it contains two or more different atoms (elements) chemically joined together An **empirical formula** shows the smallest whole number ratio of atoms of each element in a compound or molecule A **molecular formula** shows the actual number of atoms of each element in a compound or molecule
1.2	know that the mole (mol) is the unit for the amount of a substance and be able to perform calculations using the Avogadro constant L (6.02 x 10^{23} mol^{-1})
	(ii) Calculate the number of nitrogen **atoms** in 5.60 g of nitrogen gas. 2019 Jan U1 Q-22 [Avogadro constant = 6.02×10^{23} mol^{-1}] (2)
1.3	write balanced full and ionic equations, including state symbols, for chemical reactions
	(iii) Use your answers to (a)(i) and (a)(ii) to write the **ionic** equation for the reaction of iron with iron(III) chloride. Include state symbols. 2022 June U1 Q-19 You **must** show your working. (3)

1.4	understand the terms: i 'relative atomic mass' based on the ^{12}C scale ii 'relative molecular mass' and 'relative formula mass', including calculating these values from relative atomic masses *The term 'relative formula mass' should be used for compounds with giant structures.* iii 'molar mass' as the mass per mole of a substance in g mol^{-1} iv parts per million (ppm), including gases in the atmosphere
	Relative atomic mass (A_r) is the weighted average mass of an atom of an element, taking into account the abundance of all the isotopes of that element - It is measured as a ratio 1/12th the mass of a carbon-12 atom **Avogadro's constant** (6.02×10^{23}) is the number of particles in one mole of any substance (whether it be electrons, ions, atoms or molecules) A **mole** is the amount of a substance that contains the same number of particles as the number of carbon atoms in exactly 12g of the ^{12}C isotope The number of carbon atoms in exactly 12g of the ^{12}C isotope is the Avogadro's constant 6.02×10^{23} Basically, a mole is just a unit of measurement like kilograms or pounds Or more similarly, just like how a dozen is 12! A mole is simply 6.02×10^{23} of anything whether it be electrons, ions, atoms, molecules or soda cans! A dozen of books is 12 books/ A mole of oxygen is 6.02×10^{23} oxygen molecules
1.5	calculate the concentration of a solution in mol dm^{-3} and g dm^{-3} *Titration calculations are not required at this stage.*
	(molar) Concentration in mol/dm^3 Amount in moles $$n$$ Volume in dm^3 $$c \quad V$$ Concentration in ppm = $\dfrac{\text{mass of solute}}{\text{mass of solvent}} \times 10^6$
1.6	be able to use experimental data to calculate empirical and molecular formulae
	(b) A sample of a compound is analysed and found to contain **only** 3.09 g carbon, 0.26 g hydrogen and 9.15 g chlorine. 2019 Jan U1 Q-24 The molar mass of the compound is 97.0 g mol^{-1}. Calculate the molecular formula of this compound. You **must** show your working. (3)

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1.7	be able to use chemical equations to calculate reacting masses and vice versa, using the concepts of amount of substance and molar mass	
	(e) When 6.95 g of $FeSO_4.xH_2O$ is heated, 2.00 g of iron(III) oxide, 0.80 g of sulfur dioxide and 1.00 g of sulfur trioxide are produced. The only other product is water. Deduce the overall equation for the reaction using these data. State symbols are not required. You **must** show your working. [A_r values: H = 1.0 O = 16.0 S = 32.1 Fe = 55.8] (5)	2021 June U1 Q-24
1.8	be able to use chemical equations to calculate volumes of gases and vice versa, using: i the concepts of amount of substance ii the molar volume of gases iii the expression $pV = nRT$ for gases and volatile liquids	
	(iii) A sample of nitrogen gas occupied 108 cm^3 at a temperature of 25 °C and a pressure of 1.36×10^5 Pa. Using the ideal gas equation, calculate the number of moles of nitrogen gas in this sample. [$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}] (4)	2019 Jan U1 Q-22

1.9	be able to calculate percentage yields and percentage atom economies (by mass) in laboratory and industrial processes, using chemical equations and experimental results $$\text{Atom economy} = \frac{\text{molar mass of the desired product}}{\text{sum of the molar masses of all products}} \times 100$$

(ii) An experiment was carried out to produce pure, dry crystals of hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$.
Copper(II) carbonate was mixed with $50.0\,cm^3$ of $1.00\,mol\,dm^{-3}$ sulfuric acid until no more reacted.
The mass of $CuSO_4 \cdot 5H_2O$ obtained was $10.87\,g$.

Calculate the percentage yield for this reaction, giving your answer to an appropriate number of significant figures.

[Molar mass of $CuSO_4 \cdot 5H_2O = 249.6\,g\,mol^{-1}$]

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(4)

(d) Germane is a compound with the formula GeH_4.

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It can be formed by the reaction shown.

$$Na_2GeO_3 + NaBH_4 + H_2O \rightarrow GeH_4 + 2NaOH + NaBO_2$$

(i) Calculate the atom economy, by mass, for the formation of germane.
Use A_r of Ge = 72.6

(2)

1.10	be able to determine a formula or confirm an equation by experiment, including evaluation of the data	
	(d) In an experiment, 8.00 cm³ of 0.250 mol dm⁻³ sodium hydroxide, NaOH, reacted completely with 10.0 cm³ of 0.100 mol dm⁻³ phosphoric acid, H_3PO_4. Use these data to deduce the balanced equation for this reaction. You **must** show your working. (3)	2019 Oct U1 Q-24
1.11	**CORE PRACTICAL 1** **Measurement of the molar volume of a gas.**	
1.12	be able to relate ionic and full equations, with state symbols, to observations from simple test-tube experiments, to include: i displacement reactions ii typical reactions of acids iii precipitation reactions	
	Further suggested practicals: i preparation of a salt and calculating the percentage yield of product, including the preparation of a double salt, such as ammonium iron(II) sulfate from iron, ammonia and sulfuric acid ii determine a chemical formula by experiment, such as the formula of copper(II) oxide by reduction iii determine a chemical equation by experiment, such as the reaction between lithium and water, or the reaction between magnesium and an acid iv carry out and interpret the results of simple test-tube reactions, outlined in 1.12	